

## Research Article

# Conservation, Phytoremediation Potential and Invasiveness Status of Bali Botanic Garden Aquatic Plant Collection

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## ABSTRACT

Bali Botanic Garden (BBG) aspires to conduct conservation and research of eastern Indonesian plant species, including the aquatic plant species. These were important as aquatic plant species could be ecologically threatened, beneficial or even dangerous. As scientific data of BBG aquatic plant species collection was limited, we proposed this study to provide researchers and garden managers with data to conduct research, collection and maintenance of the garden aquatic plant collection. The study was carried out by sourcing list of BBG collected plant species data for its aquatic plant species. Literatures study was then carried out to gain information regarding the plant species' heavy metal phytoremediation, conservation and invasiveness status while data analysis was conducted descriptively. The study result showed that 38 collection numbers of aquatic plant species collected in BBG were placed in five sites within the garden with 94% of all the aquatic plants collection came from Lesser Sunda Islands. Eleven aquatic plants species were listed as Least Concern by IUCN Red List. Fourteen species of collected aquatic plants were proved to possessed phytoremediation potential toward numerous heavy metal pollutants, while six species were listed as an invasive alien plant species in Indonesia. All of the provided data should be enabled the botanic garden stakeholders to come up with ideas in the research and maintenance effort of BBG aquatic plant collection.

**Keywords:** aquatic plant, botanic garden, conservation, heavy metal, invasive

## INTRODUCTION

Aquatic plants species were an important constituent of the wetland ecosystem (Lacoul and Freedman, 2006). Evidence of the statement could be found in a study by Ismail *et al.* (2018) and Jha (2013) that stated the importance of the aquatic plant to influence the fish population, as well as food sources for numerous bird species. The importance of aquatic plant species for the ecosystem was not limited as shelter and food provider, but also to eliminate environmental pollutant known as phytoremediation (Peuke and Rennenberg, 2005). Alkorta and Garbisu (2001) study shows that good organic remediation result from plant species has drawn people attention to phytoremediation. Furthermore, Sumiahadi and Acar (2018) have listed several crop plants species including aquatic plant

species as *Pistia stratiotes* and *Eichhornia crassipes* were already assessed for its phytoremediation potential toward heavy metal pollutant

Despite all of its environmental importance, some aquatic plant species may also treat the ecosystem as they were considered as invasive alien plant species. Hulme (2011) described alien species as an organism that present beyond its past or present origin area and dispersal potential and invasiveness as the establishment of those alien species which caused a detrimental effect on its new region. The presence of invasive aquatic plant species could not be overlooked as it could decrease the wetland yield and services as well as altering its cycle and chemistry (Keller *et al.*, 2018). Invasive aquatic plant species induced environmental change was evidenced in the presence of *Myriophyllum aquaticum* that decreased the Dissolve Oxygen level and was in correlation with the diversity of epiphytic invertebrates and alien fish species (Kuehne *et al.*, 2016). *Hydrilla verticillata*, *E. crassipes*, *P. stratiotes*,

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*Mimosa pigra* and *Salvinia molesta* were listed as Indonesian important aquatic invasive alien plant species (Tjitrosoedirdjo, 2005).

Although of all the above-mentioned facts, numerous aquatic plant species were threatened to extinction. In Europe for example, one aquatic plant species namely *Trapa annosa* was ranked as Extinct while five other aquatic plant species were ranked as Critically Endangered, eight species listed as Endangered and 13 species considered as Vulnerable by IUCN Red List (Bilz *et al.*, 2011). Bali Botanic Garden (BBG) as an ex-situ conservation site has collected 22.432 plant specimens with 9.037 collection-number which some of them were aquatic plant species. Besides the living specimens, the garden collection was boosted even more by numerous amounts of herbarium, seed and nursery collection. However, scientific study regarding BBG aquatic plant species collection was scarce. Thus we propose this study to fill the gap. This study aims to describe aquatic plant species conservation in BBG as well as its phytoremediation potential to heavy metals pollutants and invasive status. We believe that the study result will offer baseline data for collection-based research of BBG aquatic plant species as well as enabled the garden manager to conduct research-based collection and management of the aquatic plant species.

## MATERIALS AND METHODS

### Materials

The latest list of plant species collected in BBG (July 2019) were acquired from BBG Registration Unit. The online database of The Plant List (2013) and IUCN (2019) were used to determine the scientific name of the plant species and conservation status. Setyawati *et al.* (2015) and Tjitrosoedirdjo *et al.* (2016) were used to determine the invasiveness status of the aquatic plant species in Indonesia. Various scientific publications were also consulted to gain information regarding the plant species phytoremediation potential. The comparison of BBG aquatic plant collection and Purwodadi Botanic Garden (PBG) aquatic plant collection acquired from Puspitasari and Irawanto (2016) was also conducted.

### Methods

The acquired list of plant species collection in BBG was sourced for the garden aquatic plant species collection. Obtained aquatic plant species data was then matched with The Plant List (2013) website online source to verify each plant species binomial names while IUCN (2019) website online source was consulted to acquire the plant species conservation status. Numerous scientific literatures available on

the internet was then sourced for the aquatic plant species phytoremediation potential. Setyawati *et al.* (2015) and Tjitrosoedirdjo *et al.* (2016) studies were also sourced to provide the invasiveness status of BBG aquatic plant species in Indonesia. All of the acquired data were then analyzed and presented descriptively as tables, charts and figures. Jaccard Similarity Index (JSI) was used to compare aquatic plant collection identified until its species-level collected in BBG and PBG, and calculated following Mueller-Dombois and Ellenberg (2016) as follows:

$$JSI = \frac{A}{A + B + C} \times 100\% \quad (1)$$

A = Common species

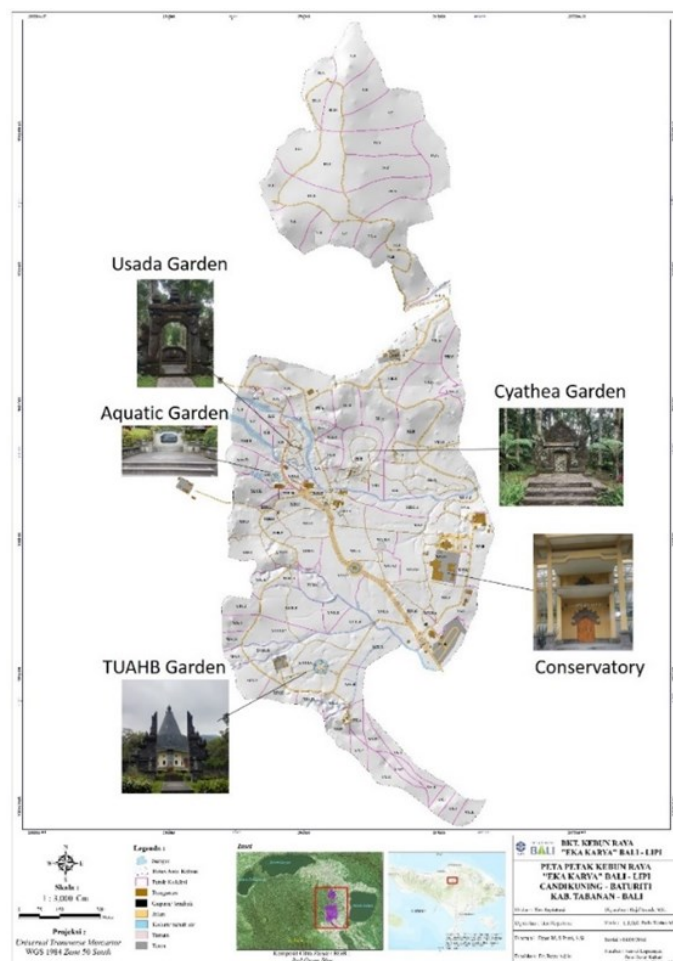
B = Unique species in BBG

C = Unique species in PBG

## RESULTS AND DISCUSSION

### Aquatic Plant Conservation in BBG

Currently, BBG conserves 38 collection number of aquatic plants, consisting of 12 families. Complete aquatic plant taxa collected by BBG presented in Table 1. BBG aquatic plant collection was placed in five locations within the garden. Separated



**Figure 1.** Aquatic Plant Species Location in BBG (©Bali botanic Garden)

**Table 1.** Aquatic Plant Taxa Collected by BBG

Species Name	Location	Origin
<b>Acanthaceae</b>		
<i>Acanthus ebracteatus</i> Vahl	Usada Garden	Bali
<i>Acanthus ilicifolius</i> L.	Usada Garden	Bali
<b>Acoraceae</b>		
<i>Acorus calamus</i> L.	Aquatic Garden, TUAHB Garden	Bali, Timor
<b>Alismataceae</b>		
<i>Sagittaria lancifolia</i> L.	Aquatic Garden	Bali
<b>Araceae</b>		
<i>Cyrtosperma beccarianum</i> A. Hay	Conservatory	Papua
<i>Cyrtosperma</i> sp.	Conservatory	Bali
<i>Pistia stratiotes</i> L.	Aquatic Garden	Bali
<b>Cyperaceae</b>		
<i>Cyperus involucratus</i> Rottb.	Aquatic Garden	Bali
<i>Cyperus papyrus</i> L.	Aquatic Garden	Bali
<i>Cyperus haspan</i> L.	Aquatic Garden	Bali
<i>Cyperus</i> sp.	Aquatic Garden	Sumba
<i>Cyperus</i> sp.	Aquatic Garden	Papua (Waigeo Is.)
<i>Cyperus</i> sp.	Aquatic Garden	Bali
<i>Fimbristylis umbellaris</i> (Lam.) Vahl	Aquatic Garden	Bali
<i>Schoenoplectiella mucronata</i> (L.) J.Jung & H.K.Choi	Aquatic Garden	Sumba
<b>Haloragaceae</b>		
<i>Myriophyllum aquaticum</i> (Vell.) Verdc.	Aquatic Garden	Bali
<b>Marsileaceae</b>		
<i>Marsilea polycarpa</i> Hook. & Grev.	Cyathea Garden	Bali
<b>Menyanthaceae</b>		
<i>Nymphoides indica</i> (L.) Kuntze	Aquatic Garden	Bali
<b>Nymphaeaceae</b>		
<i>Nymphaea elleniae</i> S.W.L. Jacobs	Aquatic Garden	Bali
<i>Nymphaea</i> "Mrs. C.W. Word"	Aquatic Garden	Bali
<i>Nymphaea pubescens</i> Willd.	Aquatic Garden	Bali
<b>Pontederiaceae</b>		
<i>Eichornia crassipes</i> (Mart.) Solms	Aquatic Garden	Bali
<i>Pontederia cordata</i> L.	Aquatic Garden	Bali
<b>Salviniaceae</b>		
<i>Azolla pinnata</i> R.Br.	Cyathea Garden	Bali
<i>Salvinia adnata</i> Desv.	Cyathea Garden	Bali
<b>Thypaceae</b>		
<i>Typha angustifolia</i> L.	Aquatic Garden	Bali

placement of aquatic plant specimens in BBG was possible since Indonesian Botanic Garden arranged its collection placement based on the plant taxonomy, utilization, origin and another category or its combination (Hadimuljono *et al.*, 2014). In case of BBG aquatic plant species, most of the specimen was placed based on its habitus similarity at the Aquatic Garden while some of the others were placed based on its taxonomy and utilization. Species that were placed based on its taxonomical status were the *A. pinnata*, *M. polycarpa* and *S. adnata* which placed in Cyathea Garden which contain fern collection of BBG (Figure 1). Aquatic plant species that placed based on its utilization as medical plant were the *A. ebracteatus* and *A. ilicifolius*, those were placed in Usada Garden which contain Balinese

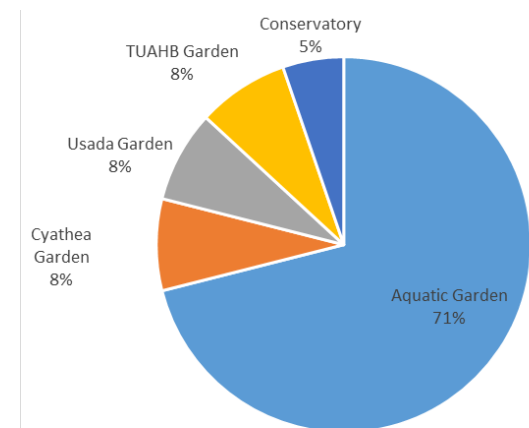
traditional medicinal plant species (Figure 1). Another plant species that placed based on its utilization was the *A. calamus* which also placed in Taman Upacara Adat Hindu Bali (TUAHB) Garden which contains plant species utilized for the Balinese Hindu ceremony due to its ceremonial use (Figure 1). Another aquatic plant species placed outside the Aquatic Garden was *Cyrtosperma beccarianum* which placed in the Conservatory as representative of the aquatic plant species, Conservatory purpose was to describe the plant species evolution process.

BBG Aquatic Garden was the garden primary site to conserve its aquatic plant specimen with 71% of all the aquatic plant collection number placed in the site (Figure 2). This was not surprising as the Aquatic Garden was purposively built to conserve

BBG aquatic plant specimen. However, as mentioned before, some of the aquatic plant species were also placed in other sites within the BBG such as Taman Upacara Adat Hindu Bali (TUAHB) Garden, Usada Garden and Cyathea Garden which contain 8% of the aquatic plant collection-number respectively (Figure 2). Another site that contains aquatic plant species was the Conservatory which contain 5% of the aquatic plant collection number (Figure 2).

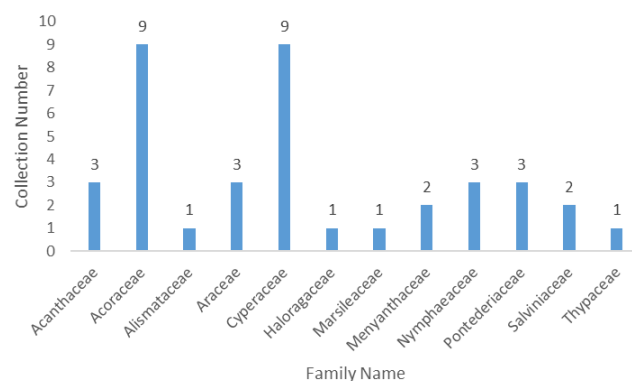
Member of Acoraceae and Cyperaceae families were composed the most collection number with nine collection-number respectively (Figure 3). Most aquatic plant specimens were collected from Bali island (84%) followed by plant specimen collected from Papua (6%), Sumba and Timor with 5% respectively (Figure 4). The aquatic plant collection site data shows us that BBG aquatic plant was collected only from Lesser Sunda Islands (Bali, Sumba and Timor) and Papua. As BBG objective is to conserve plant species from the eastern part of Indonesia, the botanic garden needs to collect aquatic plant species from another part of the region such as the Sulawesi and Moluccas.

Thirty-three aquatic plant collection-number in BBG were already identified until its species-level while four and one collection-number were identified until its genus level and as a hybrid plant specimen namely *Nymphaea* "Mrs. C.W. Word" respectively. Twenty-one species was consisting of the 33 collection-number identified until species level. The number of aquatic plants identified until its species level in BBG was almost the same as the number of aquatic species identified until its species level collected by the PBG with 17 species (Puspitasari and Irawanto, 2016). Of all plant species collected in BBG *A. calamus* was the most collected specimen with nine collection number, followed by *A. ilicifolius*, *Cyperus involucratus*, *Nymphoides indica* and *Pontederia cordata* with two collection number respectively (Figure 5).



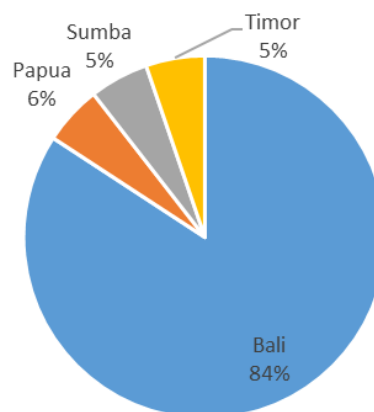
**Figure 2.** Aquatic Plant Species placement in Bali Botanic Garden

Jaccard similarity index calculation result shows that BBG and PBG aquatic plant species similarity is 11,76%. Four common species were present in these two gardens, namely *A. ilicifolius*, *A. calamus*, *Sagittaria lancifolia* L. and *Typha angustifolia*. Low similarity value between BBG and PBG means that aquatic plant collection in these two botanic gardens was very different. The result was unsurprising as both botanic gardens were situated in two very different altitudes. The presence of common plant species may suggest those species' high tolerance toward temperature gradient.



**Figure 3.** Aquatic Plant Family Collected in Bali Botanic Garden

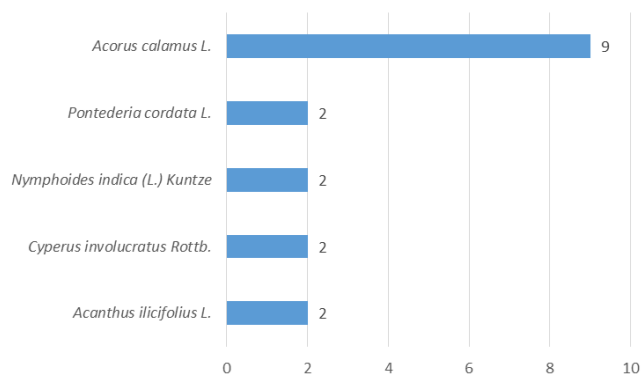
Eleven aquatic plant species collected in BBG were listed in IUCN Red List as Least Concern (Table 2). Purnomo *et al.* (2015) stated that Indonesian Botanic Gardens were able to collect 24% and cultivated 25% of Indonesian threatened plant species which defined with its Vulnerable and above IUCN Red List status with BBG was mentioned to collect more than 20 of the listed species. The absence of aquatic plant species with IUCN Red List status of Vulnerable and above in BBG collection means that aquatic plant conservation in the garden was still not able yet to conserve aquatic plant species considered as high priority species for conservation. However,



**Figure 4.** BBG Aquatic Plant Specimen Collection Sites



conservation of aquatic plant species in BBG was still able to conserve plant species with decreasing population in the wild namely *A. ebracteatus* (Ellison *et al.*, 2010). BBG was also able to conserve *A. calamus* which was important to traditionally cure several illnesses in Bali (Oktavia *et al.*, 2017). The conservation effort of these species was important to safeguard the plant species from extinction.



**Figure 5.** Five Most Collected Aquatic Plant Species in Bali Botanic Garden

### Phytoremediation Potential of BBG Aquatic Plant Collection

Literatures studies suggested that 14 aquatic plant species collected in BBG was already assessed for its phytoremediation potential. The literatures also suggest that the plant species were able to accumulate 12 heavy metal pollutants, namely Arsenic (As), Cadmium (Cd), Cobalt (Co), Chromium (Cr), Cesium (Cs), Copper (Cu), Iron (Fe), Mercury (Hg), Manganese (Mn), Nickel (Ni), Lead (Pb) and Zinc (Zn). A complete list of aquatic plant species collected in BBG with metal pollutant that they able to accumulate based on our literatures study were presented in Table 3.

To the best of our knowledge, no research

regarding aquatic plant species remediation potential has been done in BBG. This was unlike what happened in PBG which already researched the aquatic plant phytoremediation such as Irawanto *et al.* (2015) and Irawanto and Mangkoedihardjo (2015) which study the potential of *A. ilicifolius* and *Coix lacryma-jobi* to accumulate Pb and Cd. Another example of an aquatic plant phytoremediation research conducted in PBG was the phytoremediation study of *Lemma minor* and *Ceratophyllum demersum* to Pb polluted water (Munandar *et al.*, 2018) and the study of *S. molesta* and *P. stratiotes* phytoremediation toward Cu (Baroroh *et al.*, 2018).

The current absence of aquatic plant species phytoremediation research in BBG open possibilities for future research in that field as phytoremediation potential of BBG aquatic plant species which not listed in Table 3, were probably not yet assessed. Even if the plant species phytoremediation potential were already assessed, further research in phytoremediator aquatic plant species will still important to conduct, as Gratião *et al.* (2005) and Vasavi *et al.* (2010) stated that research on aquatic plant mutant impact on the environment must be conducted as genetically modified phytoremediator plant species were possible to produce.

### Invasive Alien Plant Species Status of BBG Aquatic Plant Collection

According to Setyawati *et al.* (2015) and Tjitrosoedirdjo *et al.* (2016), six aquatic plant species collected in BBG were listed as Invasive Alien Plant Species in Indonesia. Salviniaceae has contributed two species while Pontederiaceae, Cyperaceae, Haloragaceae and Araceae contributed one species respectively. Complete list of BBG aquatic plant species collection listed as invasive alien species was presented in Table 4..

**Table 2.** Conservation Status of Aquatic Species Collection in BBG Based on IUCN Red List

Species Name	Conservation Status	Literatures
<i>Acanthus ebracteatus</i> Vahl	Least Concern	Ellison <i>et al.</i> (2010)
<i>Acanthus ilicifolius</i> L.	Least Concern	Juffe Bignoli (2011)
<i>Acorus calamus</i> L.	Least Concern	Lansdown (2014)
<i>Azolla pinnata</i> R. Br.	Least Concern	Gupta and Beentje (2018)
<i>Cyperus haspan</i> L.	Least Concern	Gupta and Lansdown (2018)
<i>Cyperus papyrus</i> L.	Least Concern	Beentje and Lansdown (2018)
<i>Nymphaea pubescens</i> Willd.	Least Concern	Gupta (2011)
<i>Nymphoides indica</i> (L.) Kuntze	Least Concern	Karuppasamy <i>et al.</i> (2019)
<i>Pistia stratiotes</i> L.	Least Concern	Lansdown (2019)
<i>Schoenoplectiella mucronata</i> (L.) J.Jung & H.K.Choi	Least Concern	Lansdown (2013)
<i>Typha angustifolia</i> L.	Least Concern	Zhuang (2011)

**Table 3.** Phytoremediation Potential of BBG Aquatic Species Collection

Plant Species	Pollutant	Literatures
<i>Acanthus ebracteatus</i> Vahl	Cu	Wahwakhi <i>et al.</i> (2017)
<i>Acanthus ilicifolius</i> L.	Pb, Cd	Irawanto <i>et al.</i> (2015)
<i>Acorus calamus</i> L.	Cd	Jeelani <i>et al.</i> (2017)
	Cu	Lu <i>et al.</i> (2018); Sun <i>et al.</i> (2013)
	Cr, Zn, Fe	Sun <i>et al.</i> (2013)
	Pb	Ma <i>et al.</i> (2019)
<i>Azolla pinnata</i> R. Br.	Pb	Mandakini <i>et al.</i> (2016)
	Cd	Mandakini <i>et al.</i> (2016); Rai (2008); Arora <i>et al.</i> (2004); Sood <i>et al.</i> (2012); Talebi <i>et al.</i> (2019)
	Cr	Mandakini <i>et al.</i> (2016); Rai (2008); Arora <i>et al.</i> (2006); Sood <i>et al.</i> (2012)
	Ni	Mandakini <i>et al.</i> (2016); Arora <i>et al.</i> (2004); Sood <i>et al.</i> (2012); Talebi <i>et al.</i> (2019)
	Hg	Rai (2008); Mishra <i>et al.</i> (2009); Rai and Tripathi (2009); Sood <i>et al.</i> (2012)
	Zn, Cu	Talebi <i>et al.</i> (2019)
<i>Cyperus involucratus</i> Rottb.	Cu, Zn, Ni, Mn, Cd, Pb	Kaewtubtim <i>et al.</i> (2016)
	Cr	Meeinkuirt <i>et al.</i> (2017); Kaewtubtim <i>et al.</i> (2016)
<i>Cyperus papyrus</i> L.	As	Jomjun <i>et al.</i> (2011)
<i>Eichhornia crassipes</i> (Mart.) Solms	Cu	Lu <i>et al.</i> (2018); Hu <i>et al.</i> (2007); Sood <i>et al.</i> (2012)
	Pb	Ma <i>et al.</i> (2019)
	Hg	Sood <i>et al.</i> (2012); Molisani <i>et al.</i> (2006); Skinner <i>et al.</i> (2007)
	Cd	Mishra <i>et al.</i> (2007); Sood <i>et al.</i> (2012); Verma <i>et al.</i> (2008)
	Cr	Verma <i>et al.</i> (2008); Paiva <i>et al.</i> (2009); Sood <i>et al.</i> (2012); Mishra and Tripathi (2009); Sumiahadi and Acar (2018)
	Ni	Verma <i>et al.</i> (2008); Sood <i>et al.</i> (2012)
	As	Alvarado <i>et al.</i> (2008); Sumiahadi and Acar (2018)
	Zn	Mishra and Tripathi (2009); Sumiahadi and Acar (2018)
	Cs, Co	Saleh (2012); Sumiahadi and Acar (2018)
<i>Myriophyllum aquaticum</i> (Vell.) Verdc.	Ni, Pb, Zn	Harguinteguy <i>et al.</i> (2015); Harguinteguy <i>et al.</i> (2013)
	Co, Cu, Fe, Mn	Harguinteguy <i>et al.</i> (2013)
<i>Nymphaea pubescens</i> Willd.	Pb, Zn, Co, Cd	Kabeer <i>et al.</i> (2014)
<i>Pistia stratiotes</i> L.	Cu	Lu <i>et al.</i> (2018); Baroroh <i>et al.</i> (2018)
	Hg	Mishra <i>et al.</i> (2009); Molisani <i>et al.</i> (2006); Skinner <i>et al.</i> (2007); Sood <i>et al.</i> (2012)
	Cr	Verma <i>et al.</i> (2008); Mufarrege <i>et al.</i> (2010); Sood <i>et al.</i> (2012); Serang <i>et al.</i> (2018); Akter <i>et al.</i> (2014); Sumiahadi and Acar (2018)
	Cd	Verma <i>et al.</i> (2008); Sood <i>et al.</i> (2012); Das <i>et al.</i> (2014); Sumiahadi and Acar (2018)
	Ni	Verma <i>et al.</i> (2008); Mufarrege <i>et al.</i> (2010); Sood <i>et al.</i> (2012)
	Zn	Mufarrege <i>et al.</i> (2010); Sood <i>et al.</i> (2012)
	As	Sumiahadi and Acar (2018); Farnese <i>et al.</i> (2014)
<i>Pontederia cordata</i> L.	Cr, Fe, Cu, Zn	Sun <i>et al.</i> (2013)
<i>Sagittaria lancifolia</i> L.	Cr	Serang <i>et al.</i> (2018)
<i>Salvinia adnata</i> Desv.	Pb	George and Gabriel (2017); Kumari <i>et al.</i> (2017); Ranjitha <i>et al.</i> (2016)
	Hg	Kumari <i>et al.</i> (2017)
	Cr, Cd	Ranjitha <i>et al.</i> (2016)
	Cu	Ranjitha <i>et al.</i> (2016); Baroroh <i>et al.</i> (2018)
<i>Typha angustifolia</i> L.	Mn	Kaewtubtim <i>et al.</i> (2016)
	Cr, Zn, Cu	Bareen and Khilji (2008); Sood <i>et al.</i> (2012)
	As	Jomjun <i>et al.</i> (2011)

**Table 4.** Aquatic Species Collection of BBG Listed as Invasive Alien Plant Species in Indonesia

Species Name	Family	Origin	Literatures
<i>Azolla pinnata</i> R. Br.	Salviniaceae	Tropical Asia	Setyawati <i>et al.</i> (2015)
<i>Eichhornia crassipes</i> (Mart.) Solms	Pontederiaceae	Tropical South America	Setyawati <i>et al.</i> (2015); Tjitrosoedirdjo <i>et al.</i> (2016)
<i>Fimbristylis umbellaris</i> (Lam.) Vahl.	Cyperaceae	South East Asia	Setyawati <i>et al.</i> (2015)
<i>Myriophyllum aquaticum</i> (Vell.) Verdc.	Haloragaceae	South America	Setyawati <i>et al.</i> (2015)
<i>Pistia stratiotes</i> L.	Araceae	Africa or South America	Setyawati <i>et al.</i> (2015); Tjitrosoedirdjo <i>et al.</i> (2016)
<i>Salvinia adnata</i> Desv.	Salviniaceae	South America	Setyawati <i>et al.</i> (2015); Tjitrosoedirdjo <i>et al.</i> (2016)

*Eichhornia crassipes*, *P. stratiotes* and *S. adnata* were considered as three of the 75 important invasive alien plant species in Indonesia by Tjitrosoedirdjo *et al.* (2016). All the three species were also listed as important aquatic invasive alien plant species by Tjitrosoedirdjo (2005). *E. crassipes* was even listed by Lowe *et al.* (2000) as one of the worst invasive alien plant species. Originated from the Tropical South America *E. crassipes* was first introduced in 1894 to Bogor Botanic Garden and now present throughout Indonesia (Tjitrosoedirdjo *et al.*, 2016; Hulme 2011; Setyawati *et al.*, 2015). As with the *E. crassipes*, *P. stratiotes* was also placed in the BBG Aquatic Garden and also widely distributed in Indonesia with Africa or South America were considered as probable origin region for the species (Setyawati *et al.*, 2015; Tjitrosoedirdjo *et al.*, 2016). Both *E. crassipes* and *P. stratiotes* were firstly introduced to BBG in 2004 while Darma *et al.* (2017) reported the present of both plant species in *Tri-Danau* which consist of three lakes near BBG namely the Beratan, Buyan and Tamblingan.

Unlike the two previously mentioned important aquatic invasive alien plant species collected in BBG, *S. adnata* was placed in Cyathea Garden. Popularly known also by its synonym name of *S. molesta*, the plant species was originated from South America and distributed throughout Indonesia (Setyawati *et al.*, 2015; Tjitrosoedirdjo *et al.*, 2016). *S. adnata* was firstly introduced to BBG in 2012. The introduced specimens were collected from Buyan Lake. This was following Darma *et al.* (2017) which reported that a large portion of Buyan Lake was covered by *S. adnata*. However, the lake revitalization program carried out by the government was able to free most of the lake water bodies previously occupied by aquatic weeds including *S. adnata*.

As data of the three species, first present in the *Tri-Danau* region was absent, we were unable to conclude whether the *P. stratiotes* and *E. crassipes* specimen in the lakes were actually came from the BBG. However, careful management of all invasive

aquatic plant species which presented in BBG collection was needed to prevent the invasive plant species escape. Management of aquatic invasive alien plant species in BBG could be done as suggested by Heywood and Sharrock (2013) in *the European Code of Conduct for Botanic Gardens on Invasive Alien Species*.

## CONCLUSION

Aquatic plant species conservation in BBG is able to conserve plant species listed by IUCN Red List, as well as aquatic plant with phytoremediation and invasive potential. Eleven species of aquatic plant species in BBG are listed as Least Concern by IUCN Red List, fourteen species have phytoremediation potential and six species are listed as invasive alien plant species. The majority of the aquatic plant species are collected from Bali Island. Resulted data from this study can be used as a baseline data to conduct collection-based research in the future. On the other hand, this data also provides the garden manager with invasiveness status of aquatic plant collection to be monitored accordingly. The list also suggests that BBG should explore more aquatic plant species from another island in the eastern Indonesia region to enrich its collections.

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